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Out of *South* Africa: Pretoria's Nuclear Weapons Experience

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OUT OF *SOUTH* AFRICA

PRETORIA'S NUCLEAR WEAPONS EXPERIENCE

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The views expressed are those of the author and do not necessarily reflect the official policy or position of the United States Department of the Air Force or the United States Government.

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Abstract

The United States identifies the proliferation of weapons of mass destruction, particularly nuclear weapons, as the greatest potential threat to global security in the post-Cold War era. Despite a considerable emphasis in this area, only South Africa has voluntarily rolled back its nuclear weapons capability. (“Nuclear rollback” occurs when a nation eliminates its nuclear weapons, relinquishes at least some of the technical means to acquire nuclear weapons, or accepts a control regime to prevent it from going nuclear.) Unfortunately, South Africa’s actions apparently came in spite of U.S. nonproliferation measures.

The primary focus of this paper is the impact of key South African leaders on the successful development and subsequent rollback of South Africa’s nuclear weapons capability. It highlights the key milestones in the development of South Africa’s nuclear weapons capability. It also relates how different groups within South Africa (scientists, politicians, military, and technocrats) interacted to successfully produce South Africa’s nuclear deterrent. It emphasizes the pivotal influence of the senior political leadership to pursue nuclear rollback given the disadvantages of its nuclear means to achieve vital national interests.

The conclusions drawn from this effort are that the South African nuclear program was an extreme response to its own “identity crisis.” Nuclear weapons became a means of achieving a long-term end of a closer affiliation with the West. A South Africa yearning to be identified as a Western nation—and receive guarantees of its security—rationalized the need for a nuclear deterrent. The deterrent was intended to draw in Western support to counter a feared “total onslaught” by communist forces in the region. Two decades later, that same South Africa relinquished its nuclear deterrent—and reformed its domestic policies to secure improved economic and political integration with the West.

Several recommendations are offered for critical review of the above issues to include the need for greater international dialogue and constructive engagement with threshold nations such as India and Pakistan. Nonproliferation regimes can be used to promote mutual verification, transparency, and the resolution of mutual security concerns. More than anything, policy makers must be prepared to assist threshold nuclear states in resolving their core regional security concerns if they wish to encourage states to pursue nuclear rollback.

About the Author

Lieutenant Colonel Roy E. Horton, III (B.S., electrical engineering; M.S., strategic intelligence) was commissioned into the U.S. Air Force through the Reserve Officer Training Corps, University of Southern California, in 1979. An intelligence officer, his initial assignment was as a radar analyst for the National Aerospace Intelligence Center at Wright-Patterson AFB, Ohio. Following that tour, Lt. Col. Horton served as Chief, C3 and Electronics Group and as a Liaison Officer at Headquarters (HQ), United States Air Forces (USAF) Europe, Ramstein Air Force Base, Germany. In 1985 He was assigned to HQ USAF Intelligence where he provided critical intelligence support for “must know” operational and developmental programs like the F-117, F-22, and B-2. He then served as the Defense Intelligence Agency’s (DIA) manager for scientific and technical intelligence products on foreign air defense command and control systems. While at DIA, he deployed extensively throughout Europe and the Middle East in support of Operations Desert Shield and Desert Storm. After Air Command and Staff College, Lt. Col. Horton served in the Intelligence Division at Supreme Headquarters Allied Powers Europe in Mons, Belgium. During this period, he was the principal planner for intelligence support to NATO operations in Bosnia. Lt. Col. Horton was a National Defense Fellow with the Program in Arms Control, Disarmament, and International Security at the University of Illinois at Urbana-Champaign from July 1997 to May 1998. He assumed command of the 91st Intelligence Squadron at Ft. George G. Meade, Maryland, in August 1998, and was recently reassigned to the Air Force Technical Applications Center at Patrick Air Force Base, Florida, as Director of Operations.

Acknowledgement

For Lendra, Denise, and Brian: We spent this year 762.3 miles physically apart, but you were never far from my heart. I owe my successes to your unconditional love and support.

Introduction

Too small to be picked up by radar, the South African bomb arched up to twelve thousand meters before descending in a gentle curve across the ten kilometers between its release point and target.

After fierce debate, Pretoria's mission planners had picked the Cuban T-62 tank battalion as their primary target. Ordinarily, two battalion strongpoints could have been included in the bomb's inner kill zone, but the tanks represented most of the Third Brigade Tactical Group's combat power. The planners were willing to accept "minimal" damage to the rear of the column in order to guarantee destruction of the Cuban armor . . .

Fused for airburst, it detonated over and just outside the northwest edge of the tank battalion's laager. A boiling white-hot fireball, more than two hundred meters in diameter, speared through the night—turning darkness into flickering, man-made day for several deadly seconds . . .

The two forward battalions in the Third Brigade Tactical Group were wiped out in one swift, merciless moment. The middle two battalions lasted only five seconds longer. Ten seconds after the South African fission bomb went off, the brigade's fifth and final motor rifle battalion lay shattered in its debris-choked laager.

Several thousand men lay dead or dying among the hundreds of wrecked vehicles littering Route 47. Gen. Antonio Vega's Third Tactical Group had been annihilated.

Larry Bond, *Vortex*

Larry Bond's vision of a South Africa using nuclear weapons to stop a large-scale Cuban combined arms assault in the novel *Vortex* is eerily similar to the original purpose Pretoria claimed as the driving requirement for its pursuit of a nuclear deterrent. In reality, South Africa's leadership feared just such a Cuban assault in the late-1980s at the height of tensions with Angola and Namibia. With more than 50,000 Cuban troops along its border, South Africa faced its worst nightmare: the potential for a "total onslaught" by communist forces that the South African Defense Force (SADF) could not overcome. South Africa reportedly targeted the Angolan capital city of Luanda with a nuclear weapon in order to precipitate Western intervention into the conflict had the Cubans invaded.¹ Instead, the United States and the Soviet Union helped Angola, Namibia, and South Africa reach a negotiated settlement that achieved the withdrawal of both Cuban and South African military forces from the conflict area. Unlike the novel, South Africa's "insurance policy"² against a breakdown in the peace negotiations led to a successful outcome by securing Western intervention without a single nuclear detonation.

Just over a year after securing regional stability with its insurance policy South Africa became the first nation in history to ever rollback its nuclear capability. Nuclear rollback occurs when a nation voluntarily achieves one or more of the following: eliminates its nuclear weapons, relinquishes at least some of the technical means to acquire nuclear weapons, or accepts a control regime to prevent it from going nuclear. This paper looks at South Africa's nuclear rollback in terms of how its leadership exerted pivotal influence over its deterrent program from birth to dismantlement. The central question it addresses is how did the national identity, technical capabilities, and regional security issues coalesce into a nuclear deterrent for the Republic of South Africa (RSA) and what prompted its dismantlement?

I contend nuclear weapons were an extreme expression of South Africa's desire to be linked to the West. This created a challenge for U.S. foreign policy in balancing its opposition to apartheid (racial separateness) and the need to support nuclear nonproliferation. U.S. policy focused on pressuring the Republic of South Africa's nuclear program to achieve leverage for concessions on nonproliferation and domestic policy reform. This policy missed the chief objective of the RSA's interest in pursuing a nuclear deterrent. It focused on the symptoms of South Africa's identity crisis (for example, unsafeguarded nuclear program and apartheid), not its root causes (desire for Western security guarantees).

The paper is divided into four sections: The first describes the key milestones in the birth, life, and dismantlement of the South African nuclear program. The next section describes the dynamics of how a small core of leadership directed the actions of the program in concert with a much broader objective. The third section offers an explanation for why dismantlement was consistent with South Africa's long-term interests in seeking a close affiliation to the West. The final section discusses how the RSA nuclear program demonstrates the profound challenge to U.S. policymakers of achieving the proper policy balance to engage threshold nuclear states on proliferation issues. For the purposes of this paper, the nuclear program is broadly divided into an early, middle, and end phase. The phases roughly correspond with the initial development period from the 1950s until 1977, the development and production of deliverable nuclear weapons from 1977 until 1989, and the end phase from 1989 until its public acknowledgement in 1993.

The Program Begins

We can ascribe our degree of advancement today in large measure to the training and assistance so willingly provided by the United States of America during the early years of our programme.

A. J. Roux (Frank V. Pabian “South Africa’s Nuclear Weapons Program”)

South Africa’s quest for a nuclear deterrent capability required the acquisition of at least four basic elements: raw materials (uranium or plutonium), the ability to enrich the materials to weapons grade, trained personnel and adequate facilities, and the capability to acquire or manufacture components required for the nuclear device. The early days of South Africa’s nuclear program focused on civilian nuclear applications: the development of reactors for research and power production and the enrichment of uranium for reactor fuel. The details of this early phase are well documented. However, the critical bomb production stage of the program remains clouded by official South African government reluctance to reveal specifics and the destruction of virtually all files related to the nuclear program. Table 1 at the end of this section summarizes key milestones in the RSA nuclear weapons program.

The acquisition of raw materials was easy; South Africa’s pursuit of cheap nuclear energy was based on its abundant supply of natural uranium resources. In fact, South Africa established itself as a uranium supplier to the U.S. nuclear weapons program (and subsequently, the United Kingdom’s program) during the closing days of World War II.³ According to Richard Betts, South Africa provided approximately 40,000 tons of uranium oxide to the United States valued at approximately \$450 million.⁴ In return, South Africa sent more than ninety of its scientists and technicians for training at U.S. nuclear research installations⁵ and began its own civilian nuclear research and development program for “peaceful uses of nuclear explosives.” The United States also agreed to supply South Africa with a nuclear research reactor (SAFARI-I),⁶ train additional scientists and reactor technicians, and provide fuel for the reactor under an agreement reached in 1957. These arrangements provided South Africa with a firm foundation to conduct its civilian nuclear research and development (R&D) program. The flow of personnel, equipment, and fuel under International Atomic Energy Agency (IAEA) safeguards continued up until 1976 when the United States halted its support in response to South Africa’s refusal to sign the Nuclear Non-Proliferation Treaty (NPT).⁷

Early Phase

The success of South Africa’s civilian research coupled with its interest in using nuclear reactors for power production prompted work on uranium enrichment.⁸ The need to produce 45 percent enriched uranium for its SAFARI-I reactor led to the construction of the Y-Plant, a pilot uranium enrichment plant at Valindaba.⁹ This facility is adjacent to the Pelindaba Nuclear Research Center located approximately 35 kilometers west of Pretoria. The plant used a unique aerodynamic process to separate the U-235 from the U-238; South Africa frequently cited the need to keep the process proprietary as the rationale for blocking international inspections of the enrichment plant.¹⁰

Parallel to the fuel enrichment efforts, South Africa embarked on research into peaceful nuclear explosives (PNEs). In 1969 the Atomic Energy Board (AEB)¹¹ formed a group to evaluate the technical and economic aspects of nuclear explosives.¹² In 1971, then Minister of Mines Carl De Wet secretly approved work on “preliminary investigations” into producing nuclear explosives.¹³ No actual development work was conducted; the work was limited to theoretical investigations and literature searches on the feasibility of both implosion and gun-type nuclear devices.

The Atomic Energy Corporation (AEC) gave priority to work on the mechanical and pyrotechnical aspects of gun-type designs (similar to the U.S. atomic bomb dropped on Hiroshima) over work on an implosion design.¹⁴ The gun-type design likely gained favor because it satisfied South African safety concerns, contained no plutonium,¹⁵ used no high explosives (reduced risk of accidental detonation), and accommodated a separable design (could be stored in sections for added safety and security).¹⁶ An additional incentive may have been that a gun-type design did not necessarily require a live test to validate the design.¹⁷ In 1974, Prime Minister

Balthazar J. Vorster authorized the nuclear program to proceed under the aegis of peaceful uses (for example, large excavations, harbors, mines, and so forth) and approved the funding of a test site in the Kalahari Desert to quantify the results of their theoretical work. Despite the “peaceful” nature of all these investigations, South African officials cloaked the program in extreme secrecy.¹⁸

Despite the secrecy, visitors to South Africa during the 1970s report the AEC scientists were proud of their efforts and privately revealed their nuclear research.¹⁹ They found the scientists to be well trained and pursuing their work with an attitude of “wanting to show the world what South Africa can do.”²⁰ Many during this early stage had studied abroad, but in later years the opportunities for overseas training and contact through international conferences were severely reduced. This likely contributed to a highly parochial worldview on their part, but does not appear to have impeded their technical skills in refining the gun-type design.

The Aborted 1977 Test

South Africa proceeded from theory to practice with the construction of a nuclear test site. From 1975–76, engineers successfully drilled two test shafts more than 250 meters deep for conducting nuclear tests at the Vastrap military base located within the Kalahari Desert. The AEC planned the 1977 test to validate the nuclear device’s design less its highly enriched uranium (HEU) core (also referred to as a “cold” test).²¹ In the aftermath of India’s nuclear test in 1974, South African leaders were confident there would be little or no long-term international outrage more than an overt “declaration by detonation” of its capability to produce nuclear explosives. While the effort to develop nuclear explosives was considered a state secret, no attempt was made to conceal the supporting test infrastructure equipment and facilities. The AEC had completed the test device, described as a “monster” by 1977.²² Some reporting indicates the AEC planned to conduct a second test approximately one year later with a real HEU core following a successful cold test.²³

We did indeed receive information that South Africa was preparing for an atomic explosion, which, according to the South African authorities, was for peaceful purposes. We know what a peaceful atomic explosion is; however, it is not possible to distinguish between a peaceful atomic explosion and an atomic explosion for purposes of military nuclear testing. We therefore warned South Africa that we would regard such testing as endangering all the peace processes under way and as having a potentially serious consequences with respect to our relationship with South Africa.²⁴

Unfortunately for South Africa, a Soviet surveillance satellite detected the preparations for a nuclear test in August 1977, and Soviet authorities immediately notified the United States. While denying such a test was imminent, South Africa was forced to cancel its planned test in the face of strongly-worded demarches from several nations, including the United States, the Soviet Union, and France.²⁵ The abrupt cancellation of the test transformed South Africa’s existing program from the exploration of nuclear explosives to the development of a viable nuclear deterrent. This led to a shift in program management from the AEC to the South African Armaments Corporation (ARMSCOR).²⁶ The original nuclear test article was reportedly more than three metric tons in weight, but AEC scientists succeeded in reducing the size of the device by a factor of five.²⁷

The “Double Flash of ’79”

On 22 September 1979, a U.S. surveillance satellite detected a brief, but intense double flash of light emanating from an area over the South Atlantic near the Cape.²⁸ Coming less than two years after South Africa was forced to stand down its nuclear test in the Kalahari Desert, it brought increased attention on South Africa and the extent of cooperation with a close ally, Israel. Although it quickly denied it had conducted a test, rumors persist until the present day about possible South African involvement in a nuclear test. Analysis of its HEU production²⁹ indicates the RSA could not have produced sufficient weapons-grade uranium in time to support a test. Suspicions voiced at the time of the event pointed toward Israel as the source of the device tested with South Africa playing only a limited supporting role.³⁰ Recent press reporting appears to confirm these suspicions although understandably neither party is willing to confirm their involvement in the test.³¹

Nuclear Weapons-Related Facilities

The transition from a nuclear “device” to a nuclear deterrent led to a significant improvement in the facilities supporting the RSA nuclear program. The program essentially occupied four sets of facilities over the life of the program. Initially, the AEC secretly worked on the nuclear program in downtown Pretoria, but then moved to the Pelindaba Nuclear Research Center in the mid-1960s. At Pelindaba, the AEC designed and produced the initial nuclear device and a second, smaller device.³² AEC scientists reportedly conducted their one and only critical test for the HEU core used in South Africa’s weapons at Pelindaba.³³ Pelindaba also had facilities for machining high explosives (HE) for implosion weapons and for supporting testing and firing sites. AEC personnel monitored the production of HEU and continued advanced weapons design research for the remainder of the nuclear program—with the latter at a much slower rate and very low priority.³⁴

The transfer of nuclear weapons production responsibility to ARMSCOR led to the construction of the Kentron Circle facility (later named Advena) located approximately 20 kilometers west of Pretoria. ARMSCOR was made up of engineers vice physicists and therefore proceeded with the development and production of deliverable nuclear weapons based on the gun-type design in a “businesslike and unimaginative way.”³⁵ The Circle facility, constructed in 1980 and commissioned in May 1981, comprised two innocuous-looking buildings located deep inside the boundaries of an ARMSCOR complex used for high-speed vehicle testing on various road surfaces.³⁶ The Circle facility was also well-equipped to conduct work on implosion weapons with a capability to develop test diagnostics, HE test cells to perfect explosives placement for proper core compression and metal machining equipment for the cores.³⁷ However, ARMSCOR engineers focused the bulk of their efforts on producing a highly reliable gun-type device and never altered the original physics package design provided by the AEC.³⁸ ARMSCOR never placed a high priority on advanced weapon designs—despite extensive if slow research—until it became a possible means to extend the life of the program.

ARMSCOR successfully lobbied the government in the mid-1980s to construct the final major weapons-related facility, Advena Central Laboratories. Work began on construction of the facility to expand nuclear delivery options to ballistic missiles. This new facility appeared to be well equipped to accelerate work on advanced warhead designs and provided the capability to mate nuclear warheads to ballistic missiles.³⁹ A collaborative effort with Israel was already underway to develop an intermediate-range ballistic missile (ostensibly a “space launch program” based on the Jericho II with a maximum range of approximately 2000 kilometers).⁴⁰ The SADF believed a ballistic missile capability was necessary to counter the increasing vulnerability of its aging Buccaneer aircraft to Cuban air defenses.⁴¹

The Advena facility was completed just as the RSA nuclear program was terminated. The additional production and research capacity of the Advena facility could have increased weapons production and *simultaneously* increased the pace of work on advanced warhead designs.⁴² ARMSCOR had set the goal of upgrading the nuclear arsenal by the year 2000 when the decision was made to terminate the program. Advanced warhead designs such as implosion weapons and even boosted fission designs (to increase the yield from 15–20 kilotons to as much as 100 kilotons) were being reviewed as part of the stockpile upgrade plan.⁴³

Access to Critical Technology and Components

As noted earlier, foreign assistance was critical to the South African nuclear program during the 1970s. In addition, the absence of uniformly enforced nonproliferation controls during the 1960s and early 1970s worked in their favor as well. According to a declassified CIA estimate, “the South Africans have had little difficulty acquiring materials and technology essential to their nuclear weapons development program.”⁴⁴ South Africa had already acquired the key components needed for its fuel enrichment process and basic nuclear explosive work by the time the Carter administration moved to tighten export controls, limit training of personnel, and cutoff the supply of nuclear fuel.⁴⁵ In addition, the United States applied these controls unilaterally; many European nations continued to supply equipment to South Africa.⁴⁶

South Africa’s choice of a conservative gun-type design lends itself to a “low tech” solution that was relatively unimpeded by nonproliferation controls. Where equipment could not be obtained, South African technicians relied on creative solutions or modified uncontrolled items to serve their requirements. In one instance, the Y-Plant’s enrichment process design required the indigenous development of a reliable seal for use

between two sets of rotating machinery.⁴⁷ In another case, ARMSCOR technicians used a two-axis machine to create the complex, three-dimensional shapes needed to fabricate parts of the gun-type device.⁴⁸

The AEC and ARMSCOR personnel were also consistently aware of the need to maintain a “low profile” to avoid the attention of Western intelligence services. The acquisition of critical materials and dual-use supplies was done through a variety of suppliers and in small quantities to reduce chances of detection. South Africans tacitly acknowledge circumventing export controls to obtain selected items, but understandably refuse to name the source or methods used to acquire these items.⁴⁹ As Frank Pabian notes the overall impact of nonproliferation controls in effect when South Africa developed its weapons was to slow production and work on advanced designs by making it harder to acquire components and supplies in a consistent fashion.⁵⁰

The United States and the international community also succeeded in reducing South Africa’s prestige in the international nuclear arena. In 1977, South Africa was removed from its seat on the IAEA Board of Governors and replaced by Egypt. The seat was reserved for the “most advanced nuclear country in Africa”⁵¹ and South Africans felt it had been unfairly taken from them. To add insult to injury, South Africa was refused participation in the 1979 IAEA General Conference in an attempt to compel it to join the NPT. Ironically, the conference was being held in New Delhi, India. AEC Chief Executive Officer Waldo Stumpf noted India had detonated a nuclear explosive, refused to sign the NPT and yet they were not suffering a similar pariah status being levied upon South Africa.⁵²

Building the Weapons

In spite of these restrictions, ARMSCOR personnel established a nuclear weapons production line at their Circle facility. The AEC had produced a second device in late 1979 at Pelindaba, but it was suitable only for use in a test and was not deliverable.⁵³ ARMSCOR completed its first pre-production model in 1982, but this model was only deliverable by “kicking it out the back of a plane.”⁵⁴ ARMSCOR engineers worked to refine the overall weapon design in terms of safety, reliability, and security while holding the AEC-designed and validated physics package constant. The heavy veil of secrecy surrounding the RSA program, small staff (only about 35 of the 100 personnel employed at Circle in the early 1980s actually built the weapons), and the need to build some items in-house slowed the pace of the program.⁵⁵ The work force grew to approximately 300 personnel in 1989 with roughly half involved with weapons production.⁵⁶

At the same time, the Y-Plant was producing the necessary HEU to support the weapons program after some initial problems with the production line. The enrichment process used the centrifugal effect of spinning uranium hexafluoride and hydrogen gases inside a tube to separate the heavier uranium-238 fraction from the lighter uranium-235 fraction. The South Africans “fine-tuned” this process by trial and error over time to produce HEU. Technical problems plagued the process throughout its operation; in one instance, a chemical contamination forced the entire production line to shut down from 1979 to 1981.⁵⁷ The best estimate places the total Y-Plant HEU production at 550 kilograms.⁵⁸

Weapons Details

ARMSCOR invested heavily in refining and qualifying the various parts of the weapon with an emphasis on safety and arming features. While the gun-type design had the advantage of not using explosives⁵⁹ there were still considerable challenges to prevent accidental detonation if the weapon was dropped. ARMSCOR engineers developed a unique means of physically preventing an accidental detonation prior to final arming, but the mechanical devices involved took several years to qualify and eventually proved extremely difficult to maintain.⁶⁰ The weapons were stored as two halves in separate vaults as an additional safety feature. The design was actually divided into four segments consisting of an inner nuclear section made up of two parts containing the HEU core plus an external, two-part non-nuclear section for aerodynamic stability and guidance.⁶¹ According to ARMSCOR, the HEU core consisted of two pieces—one piece shaped like a sphere with a hole in its middle with the second piece in the shape of a cylinder designed to fit in the hole.⁶² At detonation, the cylindrical piece of HEU would be propelled down a high-strength gun barrel into the spherical piece of HEU to generate an estimated yield of 10–18 kilotons.⁶³ The production version reportedly weighed approximately 1000 kilograms, had an overall length of 1.8 meters, and a diameter of 0.65 meters.⁶⁴

The small size of ARMSCOR's actual bomb assembly group, their strong emphasis on weapons certification and qualification, the requirement to indigenously shape and manufacture several bomb components, and limited supplies of HEU held the production rate to roughly 1–2 weapons per year. The final inventory at program termination was eight active weapons: six operational (five air deliverable, one test device); one weapon under construction (intended to be a test device); and one weapon (without an HEU core assigned) for training purposes.⁶⁵ Several sources cite the total RSA nuclear inventory at “six and a half” weapons; this appears to stem from the exclusion of the training device from the accounting.⁶⁶ A unique feature of the ARMSCOR design was an apparent capability to mate the air-deliverable warheads to ballistic missiles under construction when the program terminated.⁶⁷ This flexibility could have enabled the South Africans to “mix” and “match” their limited nuclear stockpile among the available aircraft and ballistic missiles.⁶⁸

The Kalahari Revisited

The RSA's nuclear program reached full tilt in the 1987–1989 period as the regional security situation turned against South Africa. The early SADF successes against Soviet-supported Angolan forces were reversed and the Soviets were supplying these forces with superior military equipment.⁶⁹ Cuban leader Fidel Castro deployed an additional 15,000 troops in support of a series of offensive operations along the Angolan–Namibian border area. He predicted a “serious defeat” for South African forces should the need arise to launch operations deep into Namibia.

Fortunately, the increased Cuban pressure along South Africa's borders and SADF deployments in response to the Cuban's presence did not result in any major confrontations. The parties agreed to a cease-fire in August 1988, but Cuban forces remained threateningly close to the RSA's northern borders.

The South African leadership responded by carefully playing their “nuclear card” to underscore their determination not to be overwhelmed and to make it clear to the United States and the Soviet Union that an extremely unpleasant alternative to a negotiated settlement was available.⁷⁰ Prime Minister Botha ordered ARMSCOR officials to inspect and make ready the abandoned test site in the Kalahari Desert for a possible short-notice nuclear test.⁷¹ Mitchell Reiss reports the South African leaders elected this course of action as a means of signaling their resolve to the United States and the Soviet Union over reaching an acceptable solution to the withdrawal of Cuban forces.⁷²

South African Foreign Minister Pik Botha raised the stakes even further by informing the world press that “South Africa had the capability to make a nuclear weapon should we want to,” but refused to provide further details.⁷³ Whether intended as a warning or not, the comments underscored South Africa's determination not to be overrun and to see its border areas secure should peace talks stall. The end result was Cuba, South Africa, and Angola formally agreed to Namibia's independence and a timetable for the withdrawal of Cuban forces in a December 1988 agreement. Therefore, unlike in the novel *Vortex*, South Africa achieved the withdrawal of Cuban forces from its border area by enlisting the aid of the United States and the Soviet Union by demonstrating, but not detonating a nuclear weapon.

Nuclear Rollback

The withdrawal of Cuban and Soviet-supported forces from its border marked the high water mark for the RSA's use of its nuclear deterrent. ARMSCOR's efforts to breathe new life into the nuclear program could not reverse a declining trend in its priority. F. W. de Klerk was elected president of South Africa in September 1989 when Pieter W. Botha was forced to step down because of failing health. He immediately took steps to begin dismantling South Africa's nuclear arsenal and prepare for the nation's accession to the NPT. The weapons were dismantled beginning in July 1990 and work was completed by September 1991 with all of the HEU removed from the weapons and transported to Pelindaba for storage.⁷⁴ South Africa signed the NPT on 10 July 1991 and the nuclear safeguards agreement entered into force on 16 September 1991. The IAEA began its inspections in November 1991 and spent nearly two years reviewing the full scope of South Africa's nuclear program.

It was not until 24 March 1993 that President de Klerk publicly revealed to the Parliament and to the world that South Africa had embarked on an ambitious effort to build nuclear devices and had then dismantled them. Waldo Stumpf estimated the total nuclear deterrent program costs at approximately 680 million Rand (\$500 million)⁷⁵ over the lifetime of the program. Other sources estimate the total cost as closer to 7 billion rand (\$5.1 billion) given the nearly one billion rand annually allocated to the AEC at the program's peak.⁷⁶ These figures may define the program's size, but the truer measure of its effectiveness was its core leadership. This small group of politicians, scientists, military personnel, and technocrats nurtured the nuclear program, matured it into a deterrent capability, and finally terminated it when it no longer served their best interests.

Table 1. Key Events in the South African Nuclear Weapons Program⁷⁷

<i>Year</i>	<i>Activity</i>
1950s and 1960s	Scientific work on the feasibility of peaceful nuclear explosives and support to nuclear power production efforts.
1969	AEB forms group to evaluate technical and economic aspects of nuclear explosives.
1970	AEC releases report identifying wide applications for nuclear explosives.
1971	R&D for gun-type device approved for "peaceful use of nuclear explosives."
1973	AEC places research priority on gun-type design over implosion and boosted weapon designs.
1974	PM Vorster authorizes funding for work on nuclear device and preparation of test site.
1977	AEC completes assembly of nuclear device (less HEU core) for "cold test" in the Kalahari Desert. Soviet Union and United States detect preparations for the nuclear test and pressure South Africa into abandoning the test. AEC instructed to miniaturize device; groundwork laid for ARMSCOR to take program lead.
1978	Y-Plant uranium enrichment plant produces first batch of HEU. Three-phase strategic guidelines established for nuclear deterrent policy. Botha "Action Committee" recommends arsenal of seven nuclear weapons and ARMSCOR formally assumes control of program.
1979	"Double-flash" event detected; first device with HEU core produced by AEC.
1982	First deliverable device produced by ARMSCOR; work continues to improve weapon safety and reliability.
1985	ARMSCOR strategy review expands original three-phase strategy to include specific criteria to transition to next deterrent phase.
1987	First production model produced; total of seven weapons built with an eighth under construction at program termination.
1988	ARMSCOR revisits Kalahari nuclear test site and erects a large steel hangar over test shafts and prepares the shafts for a possible nuclear test. Angola, Cuba, and South Africa formally agree on Namibia's independence and schedule for Cuban troops to withdraw from Angola.
1989	F. W. de Klerk elected President and orders weapon production halted.
1990	Y-Plant formally shut down and nuclear weapons dismantlement begins.
1991	South Africa signs the NPT and enters into a comprehensive safeguard agreement.
1993	President de Klerk publicly discloses details of former South African nuclear deterrent program.

The Key Players behind the Program

It is possible that South Africa has leap-frogged the testing phase and is concentrating on the weaponizing and delivery of its nuclear explosive device. Afrikaners are a contingency-minded people and as such probably would prefer to have a deliverable nuclear weapon rather than be forced to develop one hastily in the face of a worsening security situation.

Central Intelligence Agency⁷⁸

The ebb and flow of the South African nuclear deterrent effort is all the more remarkable given the small number of personnel involved (1000 total and no more than 300 at any one period) and those actually responsible for key programmatic decisions (reportedly between six and twelve). The decisions emerged from the synthesis of four basic groups—the scientists, the politicians, the military, and the technocrats—who shaped the focus and direction of the program. The scientific zeal and drive of the AEC’s Ampie Roux and Wally Grant to demonstrate that South Africa could make a nuclear device established the technical foundation for the program.⁷⁹ Yet their work was not done in isolation from the political leadership, the support of the military on military-to-military cooperation matters, and the technocrats for actual weapons production.

The strong leadership of the ruling Nationalist Party supported the AEC’s research during the 1950s and 1960s before molding it into a key element of national strategy in the 1970s. Prime Minister B. J. Vorster presided over the decision to pursue “peaceful nuclear explosives” and the aborted Kalahari nuclear test. His successor, P. W. Botha, exerted tremendous influence over nearly the entire life of the program. He initially served as defense minister from 1966–1980 and simultaneously served as defense minister, director of the National Intelligence Service, and prime minister from 1978–1980.⁸⁰ In fact, President Botha approved the recommendation to proceed with development of a seven-weapon nuclear deterrent strategy in 1979.⁸¹ He also streamlined the State Security Council (composed of the Prime Minister, ministers of defense, foreign affairs, justice, and peace; and the senior minister) into a powerful decision-making body for national security issues in relative secrecy.⁸²

The military exerted strong influence within the State Security Council (SSC), but their role focused primarily on domestic security and conventional military operations.⁸³ The two defense ministers overseeing the nuclear program were P. W. Botha and his handpicked successor, Gen. Magnus Malan. Under Botha, the defense minister’s power was merged with that of the prime minister’s in supporting the nuclear deterrent program. Under Gen. Malan it appears the military’s direct influence over the course of the nuclear deterrent program was more limited, although they remained engaged at some level as the ultimate customer for nuclear weapons.

Finally, the technocrats—the engineers at ARMSCOR—exerted heavy influence over the nuclear program, particularly during its critical middle stage. ARMSCOR Managing Director Tielman de Waal headed a corporation that not only produced nuclear weapons, but also established the capability to mate the weapons with ballistic missiles.⁸⁴ There are also indications ARMSCOR was involved in more than just producing munitions—it also worked in developing the nuclear strategy itself. Together, these four groups formed a partnership that conceived, produced, and then discarded South Africa’s nuclear deterrent. Yet in the end, the political leadership exerted the pivotal influence over the program’s progress. Table 2 illustrates the increasing and decreasing influence exerted by the four groups over the life of the program.

Table 2. Relative Influence of Key Players

<i>Level of Influence</i>	<i>Early Phase 1950s–1977</i>	<i>Mid-Phase 1977–1989</i>	<i>End Phase 1989–1993</i>
HIGH	Politicians & Scientists	Politicians & Technocrats	Politicians
MEDIUM	Military	Military	Technocrats & Military
LOW	Technocrats	Scientists	Scientists

Whether or not the West approves, South Africa firmly plants itself in the NATO camp dedicated to the defense of the West against its enemies . . . in return, the Republic expects the West to come to its defense.
Colin Legum, *South Africa*, 1964⁸⁵

The Early Phase

For more than two decades, AEC scientists received the strong support of the South African senior leadership in its efforts to develop peaceful nuclear explosives. Their achievements were discussed in the previous section; the emphasis here is on the pivotal influence the politicians exerted during this phase. The political leadership firmly established the foundation for their long-term objective of maintaining close and continuing ties to the West. It viewed itself more as defending Western interests on the African continent—particularly against the forces of communism embodied in the Soviet Union. The SADF and the technocrats were the benefactor of increased defense budgets, but the focus was on conventional armaments. The SADF also initiated a flourishing military technology exchange program with Israel during this period—laying the foundation for future nuclear cooperation efforts.⁸⁶

The worldview of South Africa's political leadership (for example, the ruling Nationalist Party) came sharply into play during this period; the Nationalist Party aligned itself with the West and actively pursued membership in a Western alliance (to include NATO) to gain security guarantees.⁸⁷ South Africa eventually succeeded in gaining an alliance of sorts under the 1955 Simonstown Agreement to provide the British Royal Navy use of a base near Cape Town in exchange for sales of military equipment to the SADF.⁸⁸ Although rebuffed by NATO, South Africa's senior leadership were convinced their nation's geostrategic position, wealth of critical materials, and staunch opposition to communism would gain it favor—and military support—from the West. The party leaders believed these attributes would also allow them to continue their domestic policy of apartheid and maintain a favorable balance of power in the region.⁸⁹

What they had not counted on was the dual challenge of rising internal opposition by the black majority, led by the African National Congress (ANC), and international ostracism caused by its apartheid policy. As the ANC gained power and influence, the government increased the severity of its responses and lost international support. Incidents such as the March 1960 Sharpeville massacre of sixty-nine unarmed protesters significantly increased international opposition to apartheid.⁹⁰

The 1970s added another challenge to the Nationalist Party—eroding regional stability. The April 1974 overthrow of the Caetano regime in Portugal led to the breakup of its colonies in southern Africa. The cascading effect was a security threat along South Africa's northeastern border from a pro-Soviet, Marxist-Leninist government in Mozambique. Less than a year later the Alvor Accords—intended to lead to a peaceful transfer of power in Angola, Portugal's other colony—broke down almost immediately after they were signed. South Africa's attempted intervention in the ensuing civil war was unsuccessful, and yet another pro-Soviet government—this one reinforced by the presence of 50,000 Cuban troops—was established in a nation bordering South Africa to the north.

Shifting U.S. Policy

The Angola experience highlighted what South Africa regarded as lukewarm U.S. support for its battle against communism. South Africa had intervened in the civil war with the tacit support of Secretary of State Henry Kissinger and the tangible support of covert U.S. funding.⁹¹ However, the United States was forced to terminate this support when Congress and the public learned of the covert aid.⁹² Consequently, South Africa could not sustain the effort without the U.S. assistance and was forced to withdraw. At the same time, the United States canceled an existing nuclear fuel supply contract for the SAFARI-I reactor. To make matters worse, the United States refused to refund the money South Africa had already paid for the fuel.⁹³ These activities underscored to the South African leadership the limits of Western support for security and consistent economic trade. It seemed apparent to the South African leadership that some other means had to be applied to secure Western support in times of crisis.

These experiences all occurred concurrently with successful AEC preliminary work on nuclear devices. As international pressure increased over its apartheid policies, the Nationalist Party put forth the concept that South Africa faced a “total onslaught.”⁹⁴ The concept was based on four points: “the sense of an all-out threat to South Africa’s survival; a belief that its enemies are directed by the Soviet Union; a feeling of having been abandoned by the West; and a fear of massive conventional attack.”⁹⁵ From South Africa’s perspective it was alone, ill-equipped to meet regional security concerns, and being unfairly punished by the West for its domestic policies despite its staunch anti-Communist stand on the African continent.

The South African response to the challenges of a “total onslaught” was the development of a “Total National Strategy.”⁹⁶ It defined a roadmap for the use of political, military, diplomatic, and economic tools for a long-term effort to develop effective responses to internal and external national security threats. The strategy resulted in a doubling in the size of the SADF and the tripling of its defense budget over the latter half of the 1970s.⁹⁷ Under Defense Minister P. W. Botha’s guidance, the SADF was transformed to meet the new threats with the establishment of a Conventional Force and Counterinsurgency and Terrorism Force.⁹⁸ The intent was to counter the growing threat from Soviet-supported surrogates along its northern borders and counter increasing internal ANC terrorism, respectively. As a final step, the peaceful nuclear explosives program was continued—and plans were made for its eventual weaponization.

The great powers which have nuclear weapons have adopted an odd attitude. One would have thought that it would have been tactically more profitable for them to draw closer a potential member of the nuclear club, which South Africa is. Their bullying attitude could result in making us a maverick bull in the nuclear herd, and that is surely not a sound situation from their point of view. South Africa will go its own way and its own interests will be decisive.

Editorial, *Beeld*, 1977⁹⁹

Middle Period: The Rise of ARMSCOR

As discussed earlier, South Africa pursued a “peaceful atomic test” only to be pressured into aborting it by the United States and Soviet Union. This situation led to the rise of ARMSCOR as the lead agency for developing South Africa’s nuclear deterrent as Prime Minister Botha transitioned the nuclear “device” into a nuclear “weapon” and established the Republic’s first nuclear deterrent strategy.¹⁰⁰

Initially approved in 1978, it called for a three-phase strategy of nuclear deterrence. The strategy’s focus was not on warfighting, but rather on creating the proper political conditions to induce favorable Western intervention if a crisis threatened South Africa. According to Albright, the 1978 strategy was based on the following elements:

- Phase I was the standing peacetime posture of denying the existence of a South African nuclear capability. If a crisis ensued and South Africa found itself with its “back to the wall,” it would move to the next phase.
- Phase II called for covert revelation of its nuclear capability to Western countries (especially the United States). If unsuccessful,
- Phase III called for an underground test of a nuclear device to demonstrate the nuclear capability existed. If nations remained unconvinced, a contingency existed to conduct an *aboveground detonation* [emphasis added] to demonstrate an operational nuclear weapon capability.¹⁰¹

South African officials deny Phase III implied there was ever any “strategy for operational application of nuclear weapons.”¹⁰² Others believe there is evidence indicating the South African senior leadership had given strong consideration to the operational use of their nuclear arsenal. For example, ARMSCOR officials admitted during a 1995 press briefing that the Angolan capital city of Luanda was targeted for a nuclear strike had peace talks failed and hostilities broken out again in 1987.¹⁰³

Along with the political decision to establish a nuclear strategy, the middle phase also spawned what Robert Kelley refers to as the “second bomb program.” Kelley notes, “almost every nation has two nuclear

programs; one visible and the other much less so.”¹⁰⁴ In the case of South Africa, the aborted Kalahari test led to the rise of ARMSCOR and its technocrats as the “second bomb program.” ARMSCOR transformed the South African program from a fledgling exploratory effort into a full-scale weaponization and production effort. It ignored any attempts by the AEC to pursue advanced weapons designs within any priority until it became a means of extending the life of the nuclear program. Meanwhile the AEC continued to draw the attention of Western intelligence services with its focus on such advanced designs and its proximity to the Y-Plant HEU production facility.¹⁰⁵

ARMSCOR emerged as having influence over nuclear matters second only to that of the State Security Council. According to David Albright, “ARMSCOR exerted tremendous autonomy within the nuclear program.” On paper, ARMSCOR worked for the South African Air Force in developing nuclear weapons, but enjoyed unprecedented access to the state president. In fact, ARMSCOR reportedly expanded the original three-phase nuclear strategy into a 30- to 40-page document establishing specific criteria and preconditions corresponding to each phase of the original strategy.¹⁰⁶ ARMSCOR’s intent was to provide a very detailed description of the specific political, military and diplomatic conditions to be achieved at each decision point leading up to the possible use of nuclear weapons.¹⁰⁷

ARMSCOR’s involvement in developing South Africa’s nuclear deterrent strategy raises serious questions about the nature of the strategy. Both Mitchell Reiss and James Doyle viewed the original three-phase strategy as being characterized by an “...air of unreality.”¹⁰⁸ Another individual familiar with the South African nuclear program is convinced the entire strategy was developed well after the fact to obscure what was a haphazard decision-making process.¹⁰⁹ The real bottom line is the strategy targeted the United States, not an invading Soviet surrogate. The objective was to compel U.S. action; to do so required extraordinary means to insure that the weapons were secure and no possibility of inadvertent release existed.

This provides a strong rationale for why ARMSCOR personnel were uninterested in modifying the original weapons design because the focus was on credible possession of a nuclear weapon, not its specific yield. The criteria as a credible and reliable deterrent required only that it induce Western intervention; any yield (for example, anywhere between 0.001 and the desired 10–20 kiloton) would suffice.

ARMSCOR’s emphasis on arming and safety mechanisms and elaborate precautions in the storage of the weapons reflected the strong political influence over the program’s implementation. The military did not retain any day-to-day control over the devices; they were stored partially disassembled in separate vaults at ARMSCOR’s Circle facility. The vaults could only be opened with the approval of the state president and required the codes of at least four officials to gain sufficient access to the vaults to assemble a single weapon.¹¹⁰

There is limited information on the military’s influence over the nuclear weapon requirements beyond ensuring physical-electronic compatibility with their Buccaneer aircraft. Reportedly, the SADF had developed some contingency targeting lists to support the nuclear program.¹¹¹ Given the program’s political emphasis, any requirement to deliver more than one weapon to generate a response from the West would likely be counterproductive. There is little indication the military gave the employment of nuclear weapons much emphasis although they did begin practicing nuclear dive toss deliveries as early as 1976.¹¹²

The military reportedly did play a leading role in coordinating clandestine arms and technology transfers between South Africa and Israel.¹¹³ This included the transfer of approximately 50 metric tons of South African yellowcake (uranium ore concentrate) in exchange for 30 grams of tritium to support AEC work on boosted fission weapons.¹¹⁴ Other exchanges of military technology and work on joint ventures reportedly included technical knowledge acquired from the cancelled Israeli “Lavi” fighter program to the South African Cheetah fighter and the joint Israeli–South African space program.¹¹⁵ The latter effort provided South Africa with a ballistic missile delivery capability using a modified Jericho II missile.¹¹⁶

The AEC scientists were relegated from a position of “first to worst” in terms of influence over the nuclear program. They resigned themselves to researching boosted fission weapon and implosion weapon designs for which there was no customer and no hope of increased funding. ARMSCOR did bring several AEC scientists over to its Advena Central Laboratories late in 1988 to support its implosion weapon research, but the program was canceled before much work could be accomplished.

End Phase: Eliminating the Nuclear Weapons

The final phase of the nuclear program began with F. W. de Klerk's election as president of South Africa. As had been the case throughout the program, the political leadership focused on evaluating the utility of the nuclear arsenal in meeting its objective of being a part of the West. By 1989, regional security issues had been resolved and the Soviet Union was no longer viewed as being the mastermind behind every challenge to the Nationalist Party's authority. President de Klerk took full advantage of this situation in reassessing the value of the nuclear deterrent as a *means* to achieve their long-term *ends* with respect to the West.¹¹⁷ Unlike the Cold War period, the new security situation and increased international opposition to apartheid made it clear South Africa would face more, not less ostracism and economic sanctions if it retained its nuclear deterrent capability. Reiss credits President de Klerk's visionary leadership during this period as pivotal in making the choice to abandon nuclear weapons.¹¹⁸

The decline of the nuclear program (and shortly thereafter, the ballistic missile program) left ARMSCOR in a position of waning military influence as the nuclear stockpile was dismantled. It has however, attempted to increase its commercial success by converting its armament facilities to nonnuclear activities. The scientists and the military were left to provide limited technical support and security for the route used to transfer the HEU from the dismantled weapons back to a secured storage area at the Pelindaba Nuclear Research Facility, respectively.

A Nuclear Program is Dismantled

South Africa required five years to build its first nuclear device and a total of sixteen years to construct its six-weapon arsenal. Ending the program, however, took less than twenty-four months.

Mitchell Reiss, *Bridled Ambition*, 1979

At no point was the influence of South Africa's political leadership over the nuclear program greater than at its termination. The transition from a nation determined to sustain its nuclear capability into one committed to a nuclear weapons-free zone in Africa reflected a change in *means*, but not *ends* for its national security strategy. The facts of the decision-making process are straightforward: President de Klerk assumed office in 1989, terminated the program shortly thereafter, and South Africa acceded to the NPT in 1991. However, the small core leadership involved in the nuclear program remains reluctant to discuss their specific motivations for shifting South Africa's means to achieve its ends in such a short period of time.

U.S. Actions and South Africa's Reactions

The dismantlement itself was a reflection of how South Africa's leadership—primarily President de Klerk—balanced the need to rollback its nuclear capability with the concurrent requirement to radically reform its domestic policies. In many ways, the two issues of nuclear rollback and domestic reform were linked. As Frank Pabian and Mitchell Reiss note, much of the U.S. nonproliferation efforts focused on South Africa did more to isolate, rather than engage it to achieve a nuclear rollback.¹¹⁹ A key factor was the United States could not completely address the South African nuclear issue because of legal restrictions imposed by Congress to punish South Africa for its apartheid policies.

As noted earlier, the United States largely had to “go it alone” to enforce nonproliferation sanctions against South Africa. The result was largely ineffective measures to compel South Africa to accept international nuclear safeguards. One reason for the ineffectiveness of this policy was it sent very mixed signals to the government in Pretoria regarding the true nature of the sanctions.¹²⁰ In some cases the desired effect was to slow the growth or proliferation potential of South Africa's non-safeguarded nuclear program. On the other hand, the United States applied restrictions on trade and the exchange of nuclear technology and materials in response to growing disapproval of South Africa's policy of apartheid.

One of the more telling points was the 1978 Nuclear Non-Proliferation Act of 1978 (NNPA). The Carter administration used this legislation as the justification for refusing to provide nuclear fuel for the SAFARI-I reactor after South Africa had already paid for the fuel.¹²¹ According to Pabian, this action led South Africa to judge the United States as an unreliable supplier and spurred the development of an indigenous nuclear fuel production effort and to some extent, the decision to proceed with its nuclear weapons program.¹²² Consequently, U.S. policy to minimize proliferation by punishing South Africa for not joining the NPT backfired and resulted in a greater, not reduced proliferation risk.

The United States may have enacted tough legislation, but South Africa merely looked to its European suppliers to sustain its nuclear fuel production program and weapons R&D. European nations such as France, Germany, and Italy¹²³ continued to sell equipment to South Africa and are credited with supplying the bulk of the equipment needed to support its gun-type design and continued research on advanced weapons. Although the United States led the way in adopting a set of voluntary nuclear export controls under the Nuclear Suppliers Group in 1977, it was not until 1992 that dual-use equipment was included under export controls.¹²⁴

The nuclear restrictions initiated under the Carter administration continued under subsequent administrations, but a change of emphasis occurred under the Reagan administration. The Reagan administration promoted the concept of “constructive engagement” with South Africa that was intended to foster dialogue between Washington and Pretoria. However, this approach reduced policy emphasis on nuclear nonproliferation in exchange for expanded discussion of a way ahead on political reform (for example, transition to black majority rule).¹²⁵ Unfortunately, the United States could not afford to reward South Africa for progress on political reforms under this approach if nuclear nonproliferation measures were not adopted. This resulted in

a situation where U.S. nonproliferation policy could not make substantive progress on measures to curtail the South African nuclear program from 1976 until 1989.¹²⁶

South African leadership took a calculated gamble during the Cold War that U.S. regional security interests in Africa were more important than South Africa's domestic policy shortcomings. South African Prime Ministers Vorster and P. W. Botha were convinced in a situation of East versus West the United States was unwilling to give up on South Africa. Their identity as part of the West would be sustained. Had South Africa operationally employed a nuclear weapon against surrogate forces, some scholars express skepticism about U.S. willingness to come to their aid.¹²⁷ Yet the potential loss of the region's strategic materials to pro-Soviet forces might have won in a battle of interests between apartheid and increased Soviet regional influence. As in Larry Bond's novel *Vortex*, a U.S. decision to intervene on South Africa's behalf would likely first require neutralizing South Africa's remaining nuclear capability before commencing any decisive operations to repel the invading force.

But that was then . . . in today's unipolar world, a South Africa in possession of nuclear weapons has nothing to gain and everything to lose. The risks far outstrip any meager benefits gained as either a declared or undeclared nuclear state. If a nuclear stockpile was a means to securing an end in the 1980s, nuclear rollback was the means to the end for the 1990s. William Long asserts that South Africa's leadership was motivated to take the measures it did in the late 1980s to insure the West did not totally isolate it.¹²⁸ Their desire to be a part of the West, not collapsing regional security, allowed them to take advantage of the "nuclear card" to gain recognition and support from the West. When viewed in this context, the decision on South Africa's part to pursue the development of nuclear weapons—and subsequently, rollback that nuclear capability—is more plausible and logical than a purely "security-interest driven response."¹²⁹

But nuclear rollback and accession to the NPT alone, while perhaps logical in light of the absence of regional security threats, was insufficient in isolation to achieve South Africa's goal of continued Western identity. An NPT-compliant South Africa still under the rule of a minority white government practicing apartheid could not gain its coveted place in the West. Instead, international pressures to increase the economic pain of its pariah status would likely have increased.

If apartheid without nuclear weapons was considered counterproductive, there were clearly concerns about a nuclear-armed South Africa that reformed its racial policies.¹³⁰ Concerns over proliferation of nuclear technology or weapons to "rogue" states such as Libya under an ANC-led government would have likely generated equally heavy pressure to disarm. The solution, therefore, was to conduct the two activities in parallel. President de Klerk recognized the only way to secure his nation's future identity with the West lay in a dual-track policy of domestic reforms *and* nuclear rollback. Both programs had to move forward in order for South Africa to reap the fruits of economic prosperity and greater international cooperation and investment.

In the end, President de Klerk was faced with a simple choice. Continue the practices of the Botha regime or chart a new course in pursuit of a common vision of Western identity for South Africa. One means to the end via a limited nuclear deterrent capability had run its course with the end of the Cold War. It promised no economic growth and increasing domestic unrest. A second path renounced nuclear weapons and pursued meaningful dialogue toward a peaceful transition of power to the black majority. The latter meant radical changes for the Afrikaner elite, but it offered the potential for greater internal stability and increased prospects of renewed international investment.

President de Klerk is certainly deserving of the Nobel Peace Prize for his courage to make a radical course correction in his nation's path. Yet in a way, he was rewarded for adopting a selfish, yet entirely pragmatic vision of his nation's future consistent with its fundamental interests.¹³¹ There is no doubt he had to tread lightly in making steady progress to achieve these goals. The retirement of key personnel associated with the South African nuclear program¹³² and the secrecy under which the dismantlement proceeded provided the opportunity to maximize success. The nuclear program's cancellation generated some potentially dangerous backlash among those who lost their jobs. In one instance, sixteen nuclear weapons and ballistic missile technicians threatened to sell sensitive nuclear weapons information to the highest bidder unless ARMSCOR paid them one million dollars in unemployment benefits.¹³³ In another situation, two workers were fired and carefully monitored after it was learned they planned to steal nuclear weapons material.¹³⁴ These examples highlight the potential proliferation dangers inherent in nuclear rollback and suggest the need for international support to minimize these dangers.

Lessons Learned and Future U.S. Policy Implications

South Africa's decision to voluntarily dismantle its nuclear deterrent capability and embrace fully its responsibilities as a non-nuclear-weapon state will guarantee Pretoria an unprecedented place of honor in the evolution of the international non-proliferation regime.

Waldo Stumpf, "South Africa's Nuclear Weapons Program," 1995

If nothing else, Pretoria's experience underscored how quickly, quietly and relatively cheaply nuclear weapons can be acquired. It also demonstrated an important counter example to the high expectations, but low payoff observed in the Iraqi nuclear program.¹³⁵ As several scholars (Albright, Doyle, Kelley, Pabian, and Reiss) have pointed out, every nation is unique in its path to acquiring nuclear weapons and in one rare instance, rolling back that capability. The South African program demonstrated the strong pull national identity exerted over the nation's leadership to elect such an extreme approach to achieving its end of closer ties to the West.

The political leadership took advantage of its scientists' eagerness to demonstrate South Africa's technical prowess at time when the military had no rational operational requirement to pull it toward developing a nuclear deterrent. This apparent dichotomy was resolved by linking South Africa's nuclear strategy to the reaction of key Western nations and not those of its potential adversaries. From South Africa's isolated position and parochial worldview, it made sense. However, President de Klerk came to power in 1989 under a strategic environment diametrically opposed to the one P. W. Botha had encountered back in 1978. Consequently, any prospects for a favorable Western response to the existing nuclear strategy were highly unlikely. South Africa's core beliefs and interests remained unchanged, but the strategic environment framing those beliefs had changed substantially. The means to satisfy those interests had to change and that spelled the end of its nuclear deterrent capability.

For the future, Pretoria's nuclear weapons experience yields some points that may prove useful in countering proliferation challenges that are likely to worsen before conditions improve in this post-Cold War environment. The effects of these recommendations will probably manifest themselves over the long-term; if anything, South Africa's rapid nuclear rollback was a welcome exception versus the expected norm in nonproliferation policy.

Recommendations

Better Enforcement of the Nonproliferation Regime

The increasing level of international controls over nuclear technology has reduced the opportunity for a nation without a strong industrial base to follow in South Africa's footsteps.¹³⁶ Continued U.S. emphasis on arms control measures and the international nonproliferation regime (NPR) are vital to sustaining momentum for ratification of the Comprehensive Test Ban Treaty (CTBT). This also means taking a leading role in ameliorating India's concerns over the CTBT and pursuing the conclusion of a Fissile Material Cut-Off Treaty. These measures can only enhance the effectiveness of existing nonproliferation measures. The overall intent is to deny a threshold nation the opportunity to conduct any testing and eventually, restrict access to essential warhead material.

A critical element of this strategy should address greater information sharing to target the illegal removal of nuclear components or fissile materials from Russia and other newly independent states. Having finally initiated the process to address dual-use export controls, the United States and its allies must take the lead in forums such as the Nuclear Suppliers Group to establish a means of exchanging information.

Given that the information is made available, it also demands the resolve to take action to compel nations to accede to the NPR. This can include policies using diplomatic, political, economic, and if required, military instruments of national power to exert a strong influence on those nations outside the NPR. Those same instruments can be used to extend favorable economic benefits and security assurances to nations accepting

civilian nuclear safeguards while rolling back any nuclear weapons programs. It also includes reassuring our allies of our renewed commitment to their defense in regions where threshold nations continue to operate outside of the NPR.

Failure to See the World from the Threshold Nation's Perspective

Failure to see the world from the threshold nation's perspective will virtually guarantee failure of U.S. or international nonproliferation efforts directed against it. A nation's perception of its environment—not the U.S. view—will be crucial to its assessment of the value of nuclear weapons as a means to an end. For South Africa, the equation balanced in favor of nuclear weapons until the weapons became a roadblock on the path to real progress in achieving their fundamental interests. United States nonproliferation measures, motivated in large part by opposition to apartheid, did little to address the “identity crisis” that justified South Africa's nuclear deterrent capability during the Cold War. The United States must be prepared to understand and engage the nations within a region over their core interests and security concerns to promote regional stability and encourage further nuclear rollback.¹³⁷ This is not at odds with the first recommendation; rather, it ensures such instruments are used for a specific purpose to communicate a desired response by a threshold state.

Nuclear weapons will remain the “coin of the realm” for a nation that sees no other viable option to meeting its interests and security concerns. Weapons of mass destruction will continue to be perceived as an asymmetric response to an adversary's superior capabilities unless fundamental security interests can be addressed and resolved. For example, the war of words is heating up as Pakistan and India discuss new initiatives for their respective nuclear weapons programs.¹³⁸ This situation calls for U.S. intervention, either bilaterally or in concert with the other nuclear weapons states, to reduce the level of rhetoric between the two nations and focus attention on addressing the underlying concerns over national prestige and security.

Greater Emphasis on the Environmental and “Opportunity” Costs Associated with Nuclear Stockpiles

The United States and other nuclear states must raise the profile of the tremendous “opportunity” costs associated with the acquisition, maintenance, and retirement of nuclear weapons. Partial estimates for environmental clean up of U.S. nuclear weapons facilities and sites range as low as \$30 billion to well more than \$200 billion.¹³⁹ South Africa devoted a considerable portion of its indigenous resources (fiscal, technical, and human) to creating and sustaining its nuclear weapons program and supporting infrastructure. More importantly, a considerable number of its talented scientists, engineers, and technicians invested more than two decades of work into a program that diverted their creative energies from peaceful civilian research.

Defense Department programs like Cooperative Threat Reduction (CTR) are now helping Russia and newly independent states of the former Soviet Union deal with the challenges of eliminating nuclear weapons and supporting the safety and security of nuclear materials.¹⁴⁰ The CTR program could be expanded with international support to assist threshold nations in enhancing safety and security of nuclear materials and to provide economic incentives to aid in conversion of nuclear weapons-related facilities.

The bottom line is Pretoria's nuclear weapons experience proved *it is possible* to rollback a nuclear deterrent capability. A key issue in their development was a lack of security guarantees from the West as part of their core identity. The lack of clear priority for either domestic reforms or nuclear safeguards in U.S. policy toward South Africa ultimately limited the effectiveness of nonproliferation efforts. This policy confusion exacerbated South Africa's sense of isolation and contributed to the nuclear buildup. U.S. export controls did not deny South Africa key technology or materials for their weapons, but slowed the program's capability to support advanced warhead designs. More importantly, U.S. contributions to stabilizing the regional security situation altered the strategic environment in such a way to make South Africa's nuclear deterrent irrelevant and an impediment to improved international relations.

In the future, nuclear rollback challenges—and opportunities—require a focus on the regional political issues underlying regional security concerns. The United States and its allies must sustain a nuclear rollback

dialogue with nations in the Middle East and South Asia to realistically address their security concerns. In return, India, Pakistan, Israel, Syria, Egypt, Iran, Iraq, and others in these regions must be willing to thoroughly examine the core interests motivating their pursuit of nuclear weapons. For the United States, the challenge will remain “staying the course” by sustaining a high priority on regional nonproliferation policies. The failure to do so could cause the United States to repeat policy missteps that reduced its effectiveness to target the RSA nuclear program for an early retirement. Nonproliferation goals must be carefully weighed at the highest level to ensure subordination to other policy goals does not unduly decrease nuclear rollback opportunities or increase proliferation dangers.

Notes

1. John Carlin, "Pretoria Came Close to Dropping Nuclear Bomb on Luanda," *The Independent*, 30 March 1993, 12.
2. Frank V. Pabian, "South Africa's Nuclear Weapon Program: Lessons For U.S. Nonproliferation Policy," *The Nonproliferation Review* 3, no. 1, (Fall 1995), 9.
3. Richard Betts, "A Diplomatic Bomb for South Africa?" *International Security*, no. 4, (1979), 94.
4. Ibid.
5. Robert S. Jaster, "Politics and the Afrikaner Bomb," *Orbis* (Winter 1984), 826.
6. A.R. Newby-Fraser, *Chain Reaction: Twenty Years of Nuclear Research and Development in South Africa* (Pretoria: The Atomic Energy Board, 1979), 22–25.
7. Pabian, "South Africa's Nuclear Weapon Program," 2.
8. Natural uranium-238 (U-238) must be enriched to varying levels of uranium-235 (U-235) to be useful as reactor fuel or in weapons. The enrichment process requires the application of a considerable level of effort (and resources) to improve natural uranium-238 (U-238) up to a level of three-percent uranium-235 (U-235). The additional effort required to enrich uranium to weapons-grade (90 percent uranium-235 or better) is proportionally much less than to enrich uranium to the three percent level. Consequently, a nation can accelerate its weapons program by starting its enrichment process with LEU versus natural uranium. This enables it to invest the bulk of its operating capacity on producing weapons-grade uranium versus enriching natural uranium up to the low-enriched uranium level. The SAFARI-I reactor used 45-percent enriched uranium. Leonard S. Spector, *The Undeclared Bomb* (Cambridge: Ballinger Publishing Company, 1988), 436–437.
9. In the Zulu language *Valindaba* means, "we don't talk about this at all"; *Pelindaba* means "we don't talk about this anymore." J.D.L. Moore, *South Africa and Nuclear Proliferation* (London: Macmillan Press, 1987), 84.
10. Ibid, 92.
11. The South African Uranium Enrichment Corporation was merged with the Atomic Energy Board in 1982 to form the Atomic Energy Corporation or AEC.
12. Dr. David Albright, interview by author, Washington, DC, 18 February 1998.
13. Mitchell Reiss, *Bridled Ambition: Why Nations Constrain Their Nuclear Capabilities* (Washington, DC: Woodrow Wilson Press, 1995), 7–9.
14. Dr. David Albright, interview by author, Washington, DC, 26 March 1998.
15. Plutonium requires additional processing facilities and is inherently more dangerous to work with than HEU. See also Moore, *South Africa and Nuclear Proliferation*, 2–7.
16. Dr. Robert Kelley, interview by author, Las Vegas, NV, 26 Feb 1998.
17. Moore, *South Africa and Nuclear Proliferation*, 6–8.
18. DeVilliers, personal correspondence, as quoted in Reiss, *Bridled Ambition*, 8.
19. Dr. Frederick Lamb, interview by author, Urbana, IL, 20 Feb 1998.
20. Ibid.
21. There was little or no weapons-grade uranium available to support the test. James E. Doyle, "Nuclear Rollback: A New Direction for United States Nonproliferation Policy?" (Ph.D. diss., University of Virginia, 1997), 81–82.
22. Dr. Robert Kelley, interview by author, Las Vegas, NV, 26 February 1998.
23. Tests without a real HEU core are also referred to as a "cold test." J.W. de Villiers, Roger Jardine and Mitchell Reiss, "Why South Africa Gave Up the Bomb," *Foreign Affairs* (November-December 1993), 99–100.
24. Statement made by the French Minister for Foreign Affairs, M. de Guiringaud, on French radio, 22 August 1977, reproduced in UN Centre for Disarmament, *South Africa's Plan and Capability in the Nuclear Field*, Report of the Secretary-General, Document A/35/402 (New York: United Nations, 1981), 40.
25. Moore, *South Africa and Nuclear Proliferation*, 112.
26. ARMSCOR was the South African state-supported armaments company and had prior experience manufacturing munitions, field guns, helicopter gunships, some aircraft, armored vehicles, and communications equipment. They focused on making weapons to precise specifications versus the scientific philosophy of the AEC. Bernard Rabert, "South Africa's Nuclear Weapons—A Defused Time Bomb?" *AUSSENPOLITIK* III-93, 235–237.
27. Foreign press reporting on the Kalahari incident also pierced the veil of secrecy surrounding the South African nuclear program, and the general public in South Africa became aware of the nuclear program for the first time. However, unlike apartheid, the press, general public, religious leaders, and business leaders all refrained from commenting on the direction and priorities of South African national security and foreign policy initiatives. Author's interview with Dr. Albright, 18 February 1998.

28. David Albright and Corey Gay, "A flash from the past; South Africa—nuclear proliferation," *Bulletin of the Atomic Scientists* 53, no. 6 (November-December 1997), 15.
29. Robert E. Kelley, "The Iraqi and South African Nuclear Weapon Programs: The Importance of Management," *Security Dialogue* 27, no. 1 (March 1996), 37.
30. The level of sophistication associated with the test (reportedly a fission trigger for a thermonuclear weapon or possibly a 2–4 KT yield artillery shell) also tends to imply the South African's nuclear program did not substantively benefit from the Israeli test. Kelley, *ibid.*, 37.
31. Various sources report South Africa benefited from foreign assistance (particularly from Israel) in the early stages of its nuclear program but the full extent of nuclear weapons technology cooperation between Israel and South Africa remains sensitive. See David Albright's "South Africa's Secret Nuclear Weapons," *ISIS Report* (Washington, DC: Institute for Science and International Security, May 1994) and the Central Intelligence Agency's *Trends in South Africa's Nuclear Security Policies and Programs*, National Intelligence Estimate 73/5–84/CX, 5 October 1984 (declassified; FOIA case number F-1992–00809, released 27 April 1997) for additional details.
32. Dr. Robert Kelley, interview by author, Las Vegas, NV, 28 Feb 1998.
33. David Albright, "South Africa and the Affordable Bomb," *The Bulletin of the Atomic Scientists* 50, no. 4 (July-August 1994), 40.
34. Author's interview with Robert Kelley, 28 Feb 1998.
35. Robert Kelley, "The Iraqi and South African Nuclear Weapons Programs," *Security Dialogue*, Vol. 27, No. 1 (March 1996), 34.
36. One building housed the weapons development, production and storage areas. A second structure served as an environmental test facility. David Albright, "South Africa's Secret Nuclear Weapons," 9.
37. *Ibid.*
38. Author's interviews with Dr. David Albright and Dr. Robert Kelley on 18 and 28 February 1998, respectively.
39. The facility contained six dedicated HE buildings each having a unique test function using sophisticated tools like presses, machining, production equipment, warhead mating, spin balancing and flex testers to support this capability. Dr. Robert Kelley, interview by author, Las Vegas, NV, 28 February 1998.
40. The first test launch occurred in October 1989. South Africa terminated its IRBM program in 1993 shortly after it publicly announced it had dismantled its nuclear arsenal. "South Africa Tested Missile, Officials Say," *St. Louis Post-Dispatch*, 27 February 1989, 20A.
41. Other potential delivery platforms included Mirage F1, Mirage III, and Canberra aircraft. Michèle A. Flournoy and Kurt M. Campbell, "South Africa's Bomb: A Military Option?" *Orbis* (Summer 1988), 388.
42. Kelley, "Iraqi and South African Nuclear Weapons Programs," 35–36.
43. Dr. David Albright, interview by author, Washington, DC, 18 February 1998.
44. Declassified CIA estimate, *Trends in South Africa's Nuclear Security Policies and Programs*, 17.
45. Pabian, "South Africa's Nuclear Weapon Program: Lessons for US Nonproliferation Policy," 4–5, 13–14.
46. *Ibid.*, 13.
47. Albright, "South Africa's Secret Nuclear Weapons," 6.
48. Albright, "South Africa's Secret Nuclear Weapons," 13.
49. U.S. defense official, interview by author, Washington, DC, 21 November 1997.
50. Specifically, items such as high-speed cameras and flash radiography equipment and hot isostatic presses are important to an implosion-type nuclear weapons R&D program and its weaponization, respectively. Delays in the acquisition may have contributed to the low priority South Africa placed on developing implosion weapons. Pabian, "South Africa's Nuclear Weapon Program," 12.
51. Waldo Stumpf, "South Africa's Nuclear Weapons Programme," in *Weapons of Mass Destruction: Costs Versus Benefits*, ed. Kathleen C. Bailey (New Delhi: Manohar Publishers and Distributors, 1994), 68.
52. *Ibid.*
53. The device was reportedly codenamed, "MELBA." David Albright, "South Africa and the Affordable Bomb," 42.
54. Albright, *ibid.*, 43.
55. Albright, *ibid.*, 41.
56. The workforce was reduced to just over 100 by 1990. David Albright, "A Curious Conversion," *The Bulletin of the Atomic Scientists* 49, no. 5 (June 1993), 9.
57. David Albright, Frans Berkhout and William Walker, *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities and Policies* (London: Stockholm International Peace Research Institute, Oxford University Press, 1997), 380.

58. Ibid. This is more than sufficient to provide a stock of HEU for the eight weapons plus support fuel requirements for South Africa's civilian power reactors. Production estimates have ranged from 400 – 1200 kg; the actual production amount remains a confidential matter between the RSA and the IAEA.

59. A gun-type design relies on propellant charges to force the HEU plug down the barrel. For additional details see U.S. Congress, Office of Technology Assessment, *Technologies Underlying Weapons of Mass Destruction*, OTA-BP-ISC-115 (Washington, DC: U.S. Government Printing Office, 1993), 174.

60. Author's interviews with Dr. David Albright and Dr. Robert Kelley on 18 and 28 February 1998, respectively.

61. Dr. David Albright, interview by author, Washington, DC, 26 March 1998.

62. R. Jeffrey Smith, "South Africa's 16-Year Secret: The Nuclear Bomb," *The Washington Post*, 12 May 1993, A1.

63. Ibid. Some estimates placed the yield as low as 5 KT.

64. Dr. David Albright, interview by author, Washington, DC, 7 January 1998.

65. Dr. David Albright, interview by author, Washington, DC, 26 March 1998.

66. ARMSCOR reportedly produced several pre-production models to test and refine the weapons designs. The training weapon was fully operational except for the missing HEU core. U.S. defense source, interview by author, Washington, DC, 21 Nov 1997.

67. U.S. defense source, interview by author, Washington, DC, 21 Nov 1997.

68. Ibid.

69. This included sophisticated Hind attack helicopters, Mig-23 fighters, radars, and surface-to-air missiles operating as an integrated air defense network. See Bruce D. Porter's *The USSR in Third World Conflicts* (Cambridge: Cambridge University Press, 1984), 147–181 for additional details.

70. Pabian, "South Africa's Nuclear Weapon Program: Lessons for US Nonproliferation Policy," 8.

71. This action involved ARMSCOR pumping the water from the abandoned shafts, inspecting them for suitability to support an underground nuclear test, and erecting a steel hangar with a concrete floor over the test shafts. R. Jeffrey Smith, "South Africa's 16-Year Secret: The Nuclear Bomb."

72. Reiss, *Bridled Ambition*, 14.

73. Botha made the statement while in Geneva to discuss South Africa's possible accession to the NPT. Pabian, "South Africa's Nuclear Weapon Program: Lessons for US Nonproliferation Policy," 8.

74. The HEU remains at Pelindaba to the present day under IAEA monitoring and surveillance. United States efforts to purchase the HEU from South Africa have been unsuccessful. The RSA still doubts U.S. promises to supply it with nuclear fuel in the aftermath of the SAFARI-I fuel cutoff in 1976 (see note 95). David Albright and Mark Hibbs, "The ANC and the Atom Bomb," *The Bulletin of the Atomic Scientists* 49, no. 3 (April 1993), 33–35. See also Kenneth Grundy, "Bombs Away? Hardly; South Africa Developed, Built and Then Dismantled Six Atom Bombs, A Feat With Unsettling Implications for the Future," *Orlando Sentinel Tribune*, 18 April 1993, G1.

75. Waldo Stumpf, "South Africa's Nuclear Weapons Program: From Deterrence to Dismantlement," *Arms Control Today* 25, no. 10 (December 1995-January 1996), 6.

76. JW de Villiers, Roger Jardine, and Mitchell Reiss, "Why South Africa Gave Up the Bomb," 105.

77. Based on timelines in Reiss, *Bridled Ambition*, 32–35; Dr. David Albright, interview by author, Washington, DC, 18 Feb 98; and Pabian, 11.

78. Central Intelligence Agency, *Trends in South Africa's Nuclear Security Policies and Programs*, 16.

79. Reiss, *Bridled Ambition*.

80. President Botha handpicked his successors for Defense Minister and Director of NIS. He became president under the new constitution in 1980 following the abolishment of the Senate and expansion of the House of Assembly. Shelagh Gastrow, *Who's Who in South African Politics 2* (Johannesburg: Raven Press, 1987), 33.

81. Ibid.

82. Under the Botha administration, this group became the central focus for all national security policymaking and key decisions. Jaster, "Politics and the Afrikaner Bomb," 839.

83. Flournoy and Campbell, "South Africa's Bomb: A Military Option?" 390.

84. Dr. David Albright, interview by author, Washington, DC, 26 March 1998.

85. Colin Legum, *South Africa: Crisis for the West* (Pall Mall: London, 1964), 205, cited in Garth Lawrence Shelton, *Nuclear Weapons, Deterrence, and Nonproliferation: The Case of South Africa* (Ph.D. diss., University of Witwatersrand, South Africa), 126.

86. Albright, "South Africa's Secret Nuclear Weapons," 5.

87. William J. Long, "Explaining South Africa's Nuclear Weapons Policy: The Role of Beliefs in Political Outcomes" (paper presented at the annual meeting of the International Studies Association, Atlanta, GA, 1–2 November 1996), 30–31.

88. Moore, *South Africa and Nuclear Proliferation*, 63.

89. Long, "Explaining South Africa's Nuclear Weapons," 29–31.
90. Ibid, 16.
91. Flournoy and Campbell, "South Africa's Bomb: A Military Option?" 396.
92. The Congressionally-mandated Clark Amendment prohibited military assistance to any party in Angola. Pabian, "South Africa's Nuclear Weapon Program," 3.
93. Ibid. 1975 marked a period when the United States increasingly applied restrictions on transfer of nuclear technology to South Africa in retaliation for their apartheid policy. It was not until 1981 under the Reagan administration that any sort of deal was struck to allow South Africa to at least recoup a portion of its losses (reportedly some \$30 million) under the canceled contract.
94. Flournoy and Campbell, "South Africa's Bomb: A Military Option?" 395.
95. Ibid, 394–395.
96. Jaster, "Politics and the Afrikaner Bomb," 838.
97. Reiss, *Bridled Ambition*, 9.
98. Jaster, "Politics and the Afrikaner Bomb," 839.
99. Editorial, *Beeld*, 24 August 1977, cited in Jaster, "Politics and the Afrikaner Bomb," 844–845.
100. David Albright, "South Africa and the Affordable Bomb," 37, 41 and 43.
101. Dr. David Albright, interview by author, Washington, DC, 18 February 1998.
102. "Inside South Africa's Atomic Laager," *Financial Times* (London), 20 May 1993, 6.
103. John Carlin, "Pretoria Came Close to Dropping Nuclear Bomb on Luanda," *The Independent* (London), 30 March 1993, 12.
104. Dr. Robert Kelley, interview by author, Las Vegas, NV, 26 February 1998.
105. U.S. defense official, interview by author, Washington, DC 21 November 1997 and Kelley, "The Iraqi and South African Nuclear Weapon Programs," 36–38.
106. Dr. David Albright, interview by author, Washington, DC, 7 January 1998.
107. Ibid. Sources cite the existence of the document but no copies appear to have survived the purge following the RSA nuclear program's dismantlement.
108. Reiss, *Bridled Ambition*, 28.
109. Dr. Robert Kelley, interview by author, Las Vegas, NV, 26 February 1998.
110. Reportedly, the security interlocks prevented the two halves of the same weapon from being removed from their vaults at any time without high-level approval. Darryl Howlett and John Simpson, "Nuclearisation and Denuclearisation in South Africa," *Survival* 35, no. 3 (Autumn 1993), 157.
111. Reiss, *Bridled Ambition*, 16.
112. Declassified CIA estimate, *Trends in South Africa's Nuclear Security Policies and Programs*, 21.
113. Albright, "South Africa's Secret Nuclear Weapons," 5.
114. The tritium was eventually used in radioluminescent safety signs when it was apparent the boosted weapon program was stalled. According to a U.S. defense source, reports persist that HEU was diverted from the RSA to Israel in exchange for the tritium but the best accounting of the Y-Plant's production appears to discount this possibility. Albright, "South Africa's Secret Nuclear Weapons," 5.
115. Bernhard Rabert, "South Africa's Defused Nuclear Weapons—Trend Reversal in the Third World?" *AUSSENPOLITIK* I-95, 77–79.
116. Ibid.
117. Long, "Explaining South Africa's Nuclear Weapons," 37–40.
118. Reiss, *Bridled Ambition*, 329.
119. Pabian, "South Africa's Nuclear Weapon Program: Lessons for US Nonproliferation Policy," 10–16 and Reiss, *Bridled Ambition*, 28–32.
120. Doyle, "Nuclear Rollback," 94.
121. Ibid, 95
122. Pabian, "South Africa's Nuclear Weapon Program: Lessons for US Nonproliferation Policy," 5.
123. Ibid, 13.
124. Doyle, "Nuclear Rollback," 101.
125. Ibid, 98.
126. Ibid.
127. Reiss, *Bridled Ambition*, 29.
128. Long, "Explaining South Africa's Nuclear Weapons," 32–33.
129. Ibid, 22.
130. Doyle, "Nuclear Rollback," 92–93.
131. Long, "Explaining South Africa's Nuclear Weapons," 40

132. Specifically, the AEC's leading nuclear weapon proponents, Drs. Ampie Roux and Wally Grant, had retired and former Prime Minister P. W. Botha and Defense Minister General Magnus Malan had left the government. Reiss, *Bridled Ambition*, 20.

133. Instead, ARMSCOR obtained an injunction to prevent the technicians from revealing anything about the program. David Albright, "South Africa's Secret Nuclear Weapons," 19.

134. R. Jeffrey Smith, "South Africa's 16-Year Secret: The Nuclear Bomb."

135. Dr. Kelley notes that Iraq's lack of program management led its nuclear program to consume enormous amounts of resources in creating large facilities and supporting infrastructure without producing a single device. Kelley, "The Iraqi and South African Nuclear Weapon Programs," 27.

136. Dr. James Doyle, interview by author, Washington, DC 19 November 1997 and Thomas E. McNamara, "Rethinking Proliferation in the Post-Cold War Era: The Challenge of Technology", *US Department of State Dispatch* 6, no. 50-52, 928.

137. McNamara, "Rethinking Proliferation in the Post-Cold War Era," 928.

138. Harinder Baweja with Zahid Hussain, "Ghauri: Fire in the Sky," *India Today*, 20 April 1998, 38.

139. Stephen I. Schwartz and others, "Four Trillion Dollars and Counting," *The Bulletin of the Atomic Scientists* 51, no. 6 (November-December 1995), 44.

140. The CTR currently provides this assistance to Russia, Belarus, Kazakhstan and the Ukraine. Brig. Gen. Robert R. Dierker, interview by author, Washington, DC, 20 November 1997 and Reiss, *Bridled Ambition*, 326-328.